

# CIRCUIT SIMULATION FOR WIND POWER MAXIMUM POWER POINT TRACKING WITH FOUR SWITCH BUCK BOOST CONVERTER

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**Abstract**— Wind turbines have maximum mechanical power at certain wind speeds. Maximum power point tracking (MPPT) is an electronic system capable of extracting maximum wind turbine power. The purpose of this research is to improve wind power efficiency through MPPT wind power design with four switch buck-boost converter and Fuzzy control algorithm. Fuzzy control has two inputs are power changes and voltage changes and one output feeding to the pulse width modulation generator to control FSBB. Simulation results with Matlab simulink shows that wind power without MPPT produce 89% power efficiency, wind power MPPT with two switch buck-boost converter yield 90% power efficiency and emerging high ripple current. The last simulation of wind power MPPT with FSBB produces the highest efficiency of 91% with low ripple current.

**Keywords**—wind turbine, mppt, four switch buck-boost converter

## I. INTRODUCTION

Wind power is one of the power plants that use renewable energy. Wind power produces no pollution and no emissions [1]. MPPT is a technology to increase wind power efficiency by determining maximum power point at certain wind speed. There are two main components of MPPT that is DC to DC converter and control algorithm. The DC to DC converter circuit is widely used for MPPT technology in wind power [2]. Two switch buck-boost converter is a cascaded converter of Buck-Boost Converter that serves to raise and lower the input voltage [3,4].

Four switch buck-boost (FSBB) converter is the development of two switch buck-boost (TSBB) converter, where the output voltage FSBB always positive [5,6]. The FSBB converter uses four MOSFETs as the electronic switch replaces the diode function in the two switch buck-boost converter circuit, so the FSBB converter circuit has higher power efficiency than the two buck-boost converter switches. This is because the cut off voltage in the MOSFET is smaller than the forward diode voltage [7].

There is a lot of study wind power MPPT using control algorithm like fuzzy, neural network etc [8-12]. The result of the research is to know the response of the system when it reaches the maximum power point. In this paper, wind power MPPT is developed using the TSBB converter and FSBB converter, while the control algorithm uses fuzzy logic. The current study aims to reduce power losses and improve the efficiency.

## II. RESEARCH METHOD

The design of wind power MPPT based on fuzzy control using FSBB is illustrated in Figure 1. The design consists of permanent magnet synchronous generator (PMSG), the wind turbine, rectifier AC (alternating current) to DC (direct current), FSBB converter, the load resistor and fuzzy controllers. FSBB converter is modulated by PWM generator.

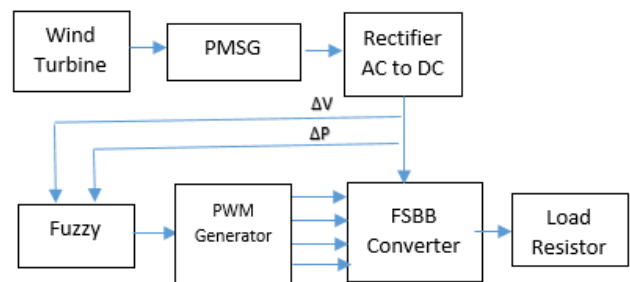


Figure 1 Design of wind power MPPT

### A. Wind Turbine

The characteristics of the wind turbine can be seen from the relationship between rotor speeds with turbine mechanical power. The mechanical power of the wind turbine for each wind speed has a maximum point at a given rotor speed, as illustrated in figure 2

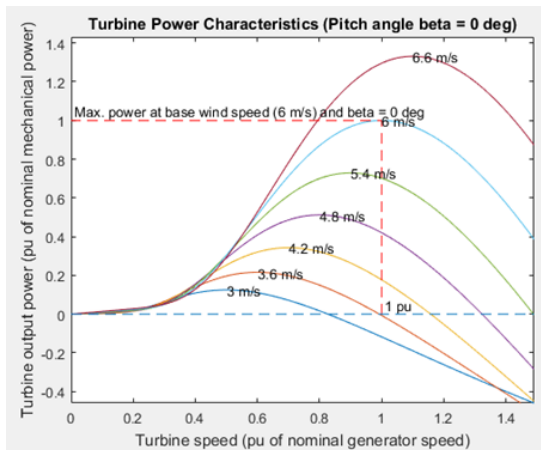


Figure 2. The power characteristics of wind turbines

Mechanical power in wind turbine  $P_m$  is a function of air density  $\rho$ , tip speed ratio (TSR)  $\lambda$ , the pitch angle  $\beta$ , radius propeller  $R$ , and wind speed  $v$  [13].

$$P_m = 0.5 \cdot \pi \cdot \rho \cdot C_p(\lambda, \beta) R^2 \cdot v^3 \quad (1)$$

The relationship between the power coefficient, TSR, and pitch angle of the  $C_p$  wind turbine ( $\lambda, \beta$ ) is written as [13]:

$$C_p(\lambda, \beta) = c_1 \left( \frac{c_2}{\lambda_t} - c_3 \beta - c_4 \right) e^{\frac{-c_5}{\lambda_t}} + c_6 \lambda \quad (2)$$

$$\frac{1}{\lambda_t} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3 + 1} \quad (3)$$

The value of  $C_1$ - $C_6$  depends on the characteristics of the wind turbine. TSR is the ratio between rotor speed  $\omega_m$  and wind speed, written by the formula [8]:

$$\lambda = \frac{\omega_m \cdot R}{v} \quad (4)$$

#### B. Four Switch Buck-Boost Converter (FSBB)

The buck-boost converter is one type of DC to DC Converter circuit that has an output voltage greater or less than the input voltage. The output voltage is of the opposite polarity the input. The two switch buck-boost converter (TSBB) is the development of buck-boost converter. The output voltage has the same polarity as the input voltage. TSBB uses diodes and transistors for switching as shown figure 3.

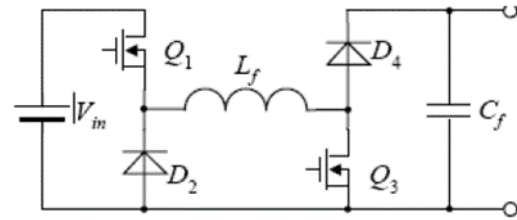


Figure 3 Two Switch Buck-Boost Converter

FSBB and TSBB have the same output voltage polarity as the input voltage. TSBB uses two diodes and two transistors, FSBB uses four transistors. The main advantage of an FSBB is that the voltage drop across the low-side transistor unipolar MOSFET can be lower than the voltage drop across the power diode of the TSBB. The FSBB has greater power efficiency than TSBB

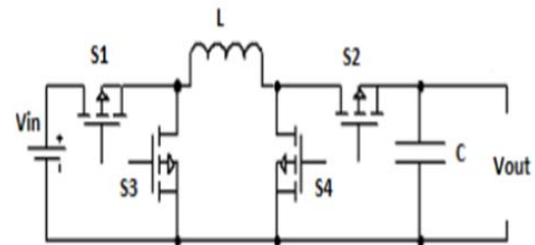


Figure 4. Four Switch Buck -Boost Converter

The output voltage of FSBB is written as [5]:

$$V_{out} = \frac{V_{in} \cdot D}{1-D} \quad (5)$$

Where  $D$  is the duty cycle value

The output current of FSBB Converter is written as:

$$I_{out} = \frac{I_{in} \cdot D}{1-D} \quad (6)$$

The amount of peak to peak ripple current  $\Delta I$  and voltage  $\Delta V_c$  is written as:

$$\Delta I = \frac{V_{in} \cdot D}{f \cdot L} \quad (7)$$



$$\Delta V_c = \frac{I_{out} \cdot D}{f \cdot C} \quad (8)$$

Where  $f$  is the switching frequency.

There are 3 modes of operation with 4 possible switches, as shown in table 1

Table 1 Switching States of the FSBB

Mode	S1	S2	S3	S4
Buck		1		0
Boost	1		0	
Buck				

Mode	$S1$	$S2$	$S3$	$S4$
Boost				

FSBB Converter uses Buck-Boost mode. The charging process occurs when the switches  $S1$  and  $S4$  become ON state, the  $S2$  and  $S3$  OFF are in OFF state. The current passes through the inductor and at the same time the capacitor voltage is directly connected to the load. FSBB operates in discharging process when switches  $S2$  and  $S3$  become ON state, the  $S1$  and  $S4$  are in OFF state. The voltage produced by the inductor is applied to the load and the capacitor.

### C. Fuzzy Logic Controller

Fuzzy controller for Wind power MPPT shown in figure 5.

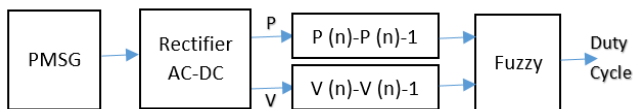


Figure 5 Scheme of the Fuzzy Control

Figure 6 illustrates the fuzzy set of the  $P(n)-P(n-1)$  input which contains five triangular membership functions.

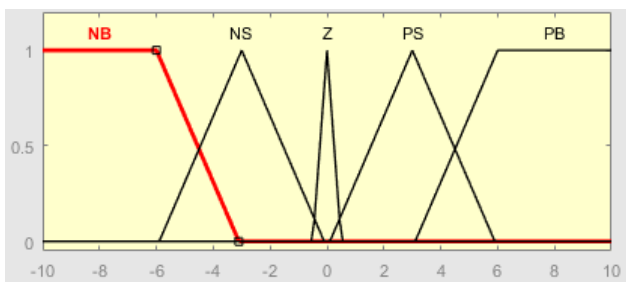


Figure 6 Member function of  $dP$

Figure 7 illustrates the fuzzy set of the  $V(n)-V(n-1)$  input which contains five triangular membership functions

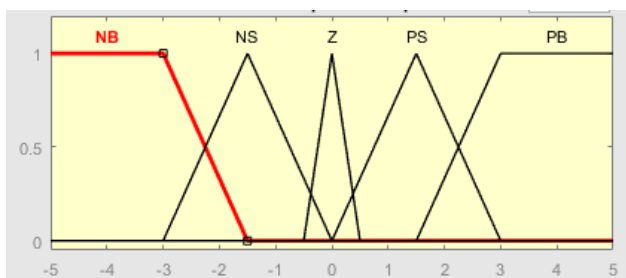


Figure 7 Member function of  $dV$

Figure 8 illustrates the fuzzy set of the duty cycle output which contains five triangular membership functions.

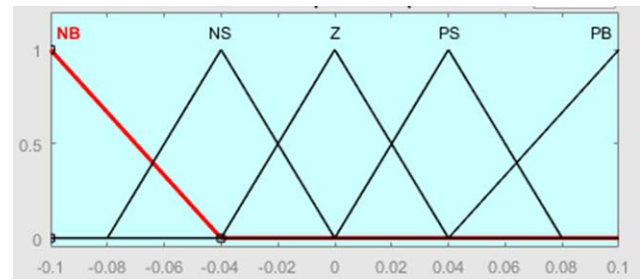


Figure 8 Member function of Duty Cycle

Determination of the rule-base of IF-THEN in the controller contains all the information to control the parameters and is based on perturb and observe, as shown in Table 2.

Table 2 Fuzzy Rules

Fuzzy Rules	P(n)-P(n-1					
V(n)-V(n-1		NB	NS	ZE	PS	PB
	NB	NB	NS	ZE	PS	PB
	NS	NS	NS	ZE	PS	PS
	ZE	ZE	ZE	ZE	ZE	ZE
	PS	PS	PS	ZE	NS	NS
	P B	PS	PS	ZE	NS	NB

## III. RESULT AND DISCUSSION

The design of wind power MPPT with four switch buck-boost converter as shown in figure 1 is simulated using matlab. Design parameter of wind power MPPT is shown in table 2.

Table 2. Design parameter of wind power MPPT

Variable	Parameter
Wind Turbine	$P_m = 200$ W
PMSG	200V 50Hz 220W
FSBB	$L = 2$ mH $C = 10\mu F$ MOSFET $R_{don} = 0.1$ ohm $F = 60$ kHz
Load	$R = 30$ ohm

The circuit simulation for wind power MPPT is explained in more detail in figure 9.

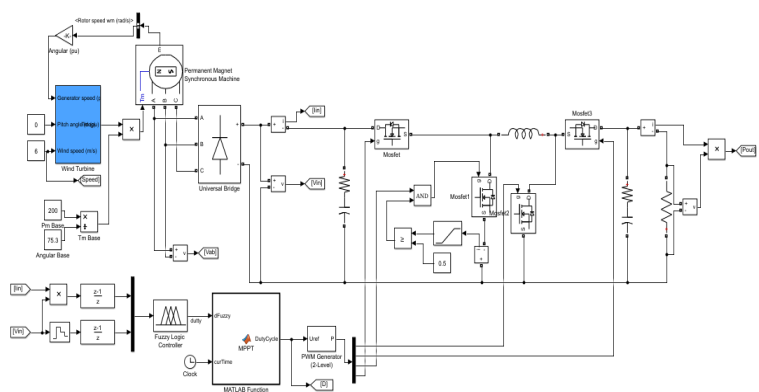


Figure 9 Schematic of wind power MPPT in Matlab

The first simulation is to test wind power without MPPT, wind turbine operated with speed 6 meter/second. Figure 10 shows the result of the simulation. The load power is 177 Watt. There is 27.5% power loss from a maximum power of 200 Watt wind turbines.

Figure 11 shows the simulation results of wind power MPPT with TSBB. The load current is 177 Watt, there is 15% power lost from 200 Watt wind turbine mechanical power.

The last simulation is to test the fuzzy MPP-based wind power using four buck-boost converter switches.

Figure 12 shows the result of the simulation. The load power loss is 9% of the wind turbine's mechanical power of 200Watt.

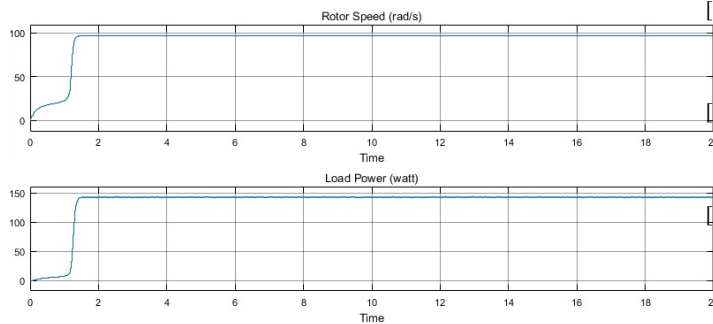


Figure 10 The Simulation of wind power without MPPT

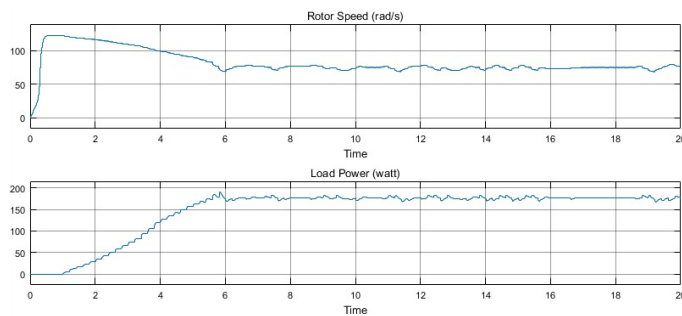


Figure 11 The Simulation f wind power MPPT with TSBB

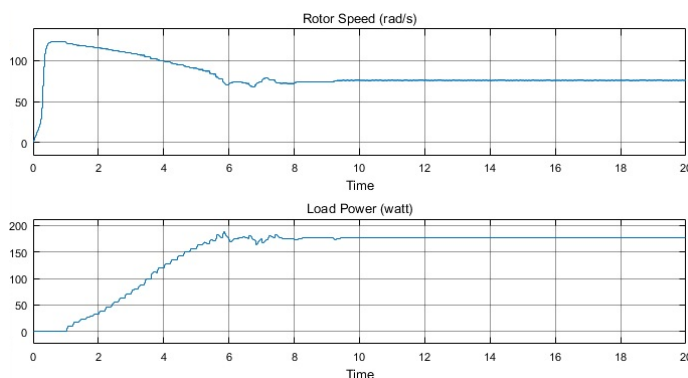


Figure 12 The Simulation of wind power MPPT with FSBB

#### IV. CONCLUSION

The simulation of wind power MPPT with four switch The simulation results show that wind power MPPT using four switch buck-boost converter is better than wind power MPPT using two switch buck-boost converter. TSBB efficiency in wind power MPPT produces 85% and current ripple appears on the load, while the FSBB produces 91% efficiency with smaller current ripple at the switching frequency of 60kHz.

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